PHILOSOPHICAL TRANSACTIONS.

I. *The Diurnal Variations of the Wind and Barometric Pressure at Bombay. By* F. CHAMBERS. *Communicated by* CHARLES CHAMBERS, *F.R.S., Director of the Colaba Observatory, Bombay.*

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1. THE object of this paper is to draw attention to a remarkable relation which has been found to exist between the diurnal variation of the wind and the double diurnal oscillation of the barometer at Bombay, and which, it is believed, will be of great interest to all meteorologists.

2. The observations made use of in the discussion are the hourly tabulations from the record of a ROBINSON'S Anemograph from June 1867 to May 1870, the hourly observations of the barometer and temperature of the air for the same period, and the corresponding pressure of vapour (calculated from the readings of the dry- and wet-bulb thermometers), and also some particular results of later date which will be introduced in the course of the inquiry. A full description of the various instruments and the methods of observation and reduction is given in the introduction to the "Bombay Magnetical and Meteorological Observations, 1865–70;" but it may be well briefly to recapitulate here the method of reducing the anemograph indications, as it is entirely owing to its mathematical exactness that the results now brought forward have been obtained, and it is therefore deserving of special attention.

The wind of every hourly interval is resolved into a north or south wind and an east or west wind of such velocities, that, if they blew together, the resulting movement and direction would be the same as is actually observed. The formulæ by which these resolutions are effected are:—

Velocity of wind from north or south $=m \cos (n\times 22\frac{1}{2}$ degrees) . . . . . . (1)

Velocity of wind from east or west $=m \sin (n\times 22\frac{1}{2}$ degrees). . . . . . . (2)

Where m is the movement observed and n the number of the direction-space under which the wind of the hourly interval is classed, the circle being divided into sixteen spaces, which are numbered consecutively from 0 to 15, and correspond respectively to the directions N., N.N.E., N.E., &c.; hence the quantity calculated from (1) will repre-

sent either a north or a south wind, according as its sign is positive or negative, and similarly for the east or west wind calculated from (2). The algebraical averages of the north and south and of the east and west component winds may then be taken separately for any given period, and these will, when combined, truly represent the average velocity and direction of the wind for that period. Such averages have been calculated for each hour of the day in the whole period from June 1867 to May 1870, or three complete years. They are given in the following Table, along with the corresponding averages of most of the other meteorological elements.

TABLE I.—Mean Values of Meteorological Elements for each hour of the day from May 1867 to June 1870, and their Mean Diurnal Variations for the same period.

Bombay Civil Hours.	Wind. Mean N. or S. component.	Wind. Variation of N. or S. component.	Wind. Mean E. or W. component.	Wind. Variation of E. or W. component.	Bombay Civil Hours.	Barometer pressure. Reduced to 32° F. Mean.	Barometer pressure. Reduced to 32° F. Variation.	Pressure of vapour. Mean.	Pressure of vapour. Variation.	Pressure of dry air. Mean.	Pressure of dry air. Variation.	Temperature of air. Mean.	Temperature of air. Variation.
0 to 1	1·03 N.	1·04 S.	4·46 W.	1·79 E.	0	29·824	+0·004	0·781	−0·002	29·043	+·006	77·3°	−2·1°
1 „ 2	1·07 N.	1·00 S.	3·96 W.	2·29 E.	1	·810	− ·010	·777	− ·006	·033	−·004	76·9	−2·5
2 „ 3	0·93 N.	1·14 S.	3·56 W.	2·69 E.	2	·797	− ·023	·773	− ·010	·024	−·013	76·7	−2·7
3 „ 4	1·10 N.	0·97 S.	3·09 W.	3·16 E.	3	·791	− ·029	·768	− ·015	·023	−·014	76·3	−3·1
4 „ 5	1·27 N.	0·80 S.	2·52 W.	3·73 E.	4	·793	− ·027	·762	− ·021	·031	−·006	76·1	−3·3
5 „ 6	1·27 N.	0·80 S.	1·96 W.	4·29 E.	5	·804	− ·016	·756	− ·027	·048	+·011	75·8	−3·6
6 „ 7	1·00 N.	1·07 S.	1·19 W.	5·06 E.	6	·822	+ ·002	·754	− ·029	·068	+·031	75·7	−3·7
7 „ 8	0·73 N.	1·34 S.	0·86 W.	5·39 E.	7	·844	+ ·024	·760	− ·023	·084	+·047	76·4	−3·0
8 „ 9	0·77 N.	1·30 S.	1·09 W.	5·16 E.	8	·864	+ ·044	·767	− ·016	·097	+·060	77·9	−1·5
9 „ 10	0·67 N.	1·40 S.	2·16 W.	4·09 E.	9	·877	+ ·057	·772	− ·011	·105	+·068	79·4	0·0
10 „ 11	0·43 N.	1·64 S.	4·39 W.	1·86 E.	10	·876	+ ·056	·774	− ·009	·102	+·065	80·7	+1·3
11 „ 12	0·83 N.	1·24 S.	7·12 W.	0·87 W.	11	·862	+ ·042	·777	− ·006	·085	+·048	82·0	+2·6
12 „ 13	1·67 N.	0·40 S.	9·92 W.	3·67 W.	12	·839	+ ·019	·783	·000	·056	+·019	83·2	+3·8
13 „ 14	2·09 N.	0·02 N.	11·39 W.	5·14 W.	13	·816	− ·004	·795	+ ·012	·021	−·016	84·0	+4·6
14 „ 15	3·17 N.	1·10 N.	12·72 W.	6·47 W.	14	·793	− ·027	·805	+ ·022	28·988	−·049	84·3	+4·9
15 „ 16	3·93 N.	1·86 N.	12·99 W.	6·74 W.	15	·778	− ·042	·807	+ ·024	·971	−·066	84·3	+4·9
16 „ 17	4·70 N.	2·63 N.	12·66 W.	6·41 W.	16	·773	− ·047	·811	+ ·028	·962	−·075	83·7	+4·3
17 „ 18	4·83 N.	2·76 N.	11·59 W.	5·34 W.	17	·778	− ·042	·803	+ ·020	·975	−·062	82·1	+2·7
18 „ 19	4·87 N.	2·80 N.	10·02 W.	3·77 W.	18	·791	− ·029	·802	+ ·019	·989	−·048	80·4	+1·0
19 „ 20	4·40 N.	2·33 N.	8·39 W.	2·14 W.	19	·809	− ·011	·800	+ ·017	29·009	−·028	79·5	+0·1
20 „ 21	3·43 N.	1·36 N.	7·32 W.	1·07 W.	20	·826	+ ·006	·800	+ ·017	·026	−·011	79·0	−0·4
21 „ 22	2·47 N.	0·40 N.	6·36 W.	0·11 W.	21	·839	+ ·019	·795	+ ·012	·044	+·007	78·5	−0·9
22 „ 23	1·73 N.	0·34 S.	5·52 W.	0·73 E.	22	·842	+ ·022	·787	+ ·004	·055	+·018	78·0	−1·4
23 „ 0	1·20 N.	0·87 S.	4·76 W.	1·49 E.	23	·835	+ ·015	·782	− ·001	·053	+·016	77·5	−1·9
	2·07 N.	......	6·25 W.			29·820	......	0·783	......	29·037	......	79·4	

The observations of the barometer and thermometers were made seven minutes and five minutes respectively after the full hour.

These variations are also represented graphically by figures 1, 2, 3, 4 and 5, Plate XXXIV.

3. From the hourly values of the variation of the barometer given above, the constants in the first three terms of the right-hand member of BESSEL'S formula,

$$E = B_1 \sin(\theta + C_1) + B_2 \sin(2\theta + C_2) + B_3 \sin(3\theta + C_3) + \&c., \quad . \quad . \quad . \quad (3)$$

have been calculated and found to be

$$B_1 = \cdot 0179, \qquad C_1 = 337^\circ\ 17',$$
$$B_2 = \cdot 0385, \qquad C_2 = 157\ \ 13,$$
$$B_3 = \cdot 0014, \qquad C_3 = \ 25\ \ \ 0;$$

and from these values we find that the maxima and minima and the times of their occurrence are as follows, viz.:—

			h	m
The first minimum in the day . .	= −·0293	at	3	29
„ „ maximum „ „ . .	= +·0551	„	9	32
„ second minimum „ „ . .	= −·0484	„	16	1
„ „ maximum „ „ . .	= +·0228	„	22	5

Now marking these times along the course of the wind-curve (fig. 1), we see that they and the centre of the curve are all of them almost exactly in the same straight line—that the straight line being drawn through the centre so as to pass as close as possible to each of the marks so laid down divides the curve into four branches, two turned to the north of the line and two turned to the south of it—and that the direction of the line itself is the same as the general direction of the whole curve. We now see that the curve is such a one as would be formed by two distinct variations being superimposed the one on the other—one, the movement in the direction of the line, having a single period like the temperature-curve (fig. 5), and the other, the north and south movement, having a double period, and in this respect like the barometer-curve (fig. 2), but differing from it in that it passes through its mean positions at the four times when the latter is at its extreme positions, and *vice versâ*. A closer comparison of the two curves (1 and 2) shows that when the wind-curve passes to the north of the line A B, the barometer begins to rise, and the more rapidly the further the curve departs from the line, and ceases to do so on the return of the curve back to the line; similarly the barometer falls when the curve passes to the south of the line, its rate of descent being approximately proportional to the distance of departure of the wind-curve from the line.

4. There can be no doubt that the greater part of the more extensive east and west movement is the land- and sea-breeze; and this feature and the generally accepted theory which explains it have been already commented upon in Appendix I. of the Bombay Magnetical and Meteorological Observations for 1865 to 1870, on "The Normal Winds of Bombay." The explanation of the double diurnal variation which we find is superimposed at Bombay on the land- and sea-breeze is not, however, so apparent; and before a complete view of the nature of this variation could be obtained, it would be necessary to eliminate from the whole curve that part which may be considered due to the pure land- and sea-breeze; but the precise nature of this part is itself unknown, and the elimination could only be effected by a comparison of the curve for Bombay with that of some other place, where, other conditions being similar, the land- and sea-breeze is either entirely absent or reversed in direction, as, for instance, at Madras; but similar results for such a place are not yet available, and an approximate view is all that can be afforded at present.

5. The principal features of the pure land- and sea-breeze will be more clearly exhibited in the following manner. Assuming that its direction is completely represented by the straight line A B, fig. 1, which is inclined to the east and west line at an angle

of $18\frac{1}{2}°$, then all the hourly points being projected in a north or south direction upon this line will give a series of points which will represent the variation of the land- and sea-breeze combined with any of the diurnal variation which may exist in the same direction, similar to that which does exist in a north and south direction. The variation is given below, and has been obtained by multiplying the east components of the variation of the wind for each hour, given in Table I., by secant $18\frac{1}{2}°$.

TABLE II.—Mean Land- and Sea-Breeze at Bombay.

Bombay Civil Hours	0 to 1.	1–2.	2–3.	3–4.	4–5.	5–6.	6–7.	7–8.
Velocity of wind in miles per hour	E.S.E. 1·89	E.S.E. 2·41	E.S.E. 2·84	E.S.E. 3·33	E.S.E. 3·93	E.S.E. 4·52	E.S.E. 5·33	E.S.E. 5·68
Bombay Civil Hours	8 to 9.	9–10.	10–11.	11–12.	12–13.	13–14.	14–15.	15–16.
Velocity of wind in miles per hour	E.S.E. 5·44	E.S.E. 4·31	E.S.E. 1·96	W.N.W. 0·92	W.N.W. 3·87	W.N.W. 5·42	W.N.W. 6·82	W.N.W. 7·10
Bombay Civil Hours	16 to 17.	17–18.	18–19.	19–20.	20–21.	21–22.	22–23.	23–0.
Velocity of wind in miles per hour	W.N.W. 6·76	W.N.W. 5·63	W.N.W. 3·97	W.N.W. 2·26	W.N.W. 1·13	W.N.W. 0·12	E.S.E. 0·77	E.S.E. 1·57

It is also represented graphically by fig. 6, which will be seen to be remarkably like the temperature-curve (fig. 5) in general character, but from about 1 to 2 hours later in phase. This general resemblance is satisfactorily explained by the theory already adverted to; for the producing cause of the land- and sea-breeze, according to that theory, being the difference of temperature indicated by two temperature-curves, viz. that of the land and that of the sea (which presumably differ from each other only in extent and not in form), will also be represented by a temperature-curve of a like nature; and it is to be expected therefore that the land- and sea-breeze, when represented as in fig. 6, will have some such resemblance to the temperature-curve as that which it exhibits. But fig. 6 has at the same time very definite and distinctive features peculiar to itself; amongst these may be mentioned:—

1st. Its rapid transition from east to west, moving from $10\frac{1}{2}$ hours to $12\frac{1}{2}$ hours through nearly half of its whole range, which is much more rapid than the corresponding change of the temperature-curve.

2nd. From 18 hours to 6 hours the curve is first convex and afterwards slightly concave downwards, having a point of inflection about midnight, while the temperature-curve is convex downwards during the whole of the same interval.

These features are what might be expected from the superposition on the land- and sea-breeze of an east and west double diurnal variation of the wind which attains its maximum east positions at about the same hours at which the barometer reaches its

maxima, and attains its maximum west positions at about the same hours at which the barometer reaches its minima, and passes through zero at the times when the barometer passes through its mean positions. A strong reason for believing that these features are produced by the superposition of such a variation, is afforded by the mean diurnal variation of the east or west components of the wind for the months of July and August alone; for during these months the land- and sea-breeze has almost entirely disappeared, because the difference between the daily ranges of temperature of the land and sea is then very small, and the wind variation then found is of the kind here described, and would, when superimposed upon the mean temperature-curve for the year, produce a curve having similar features to those enumerated as peculiar to the curve which represents the land- and sea-breeze. The variation is given in Table III., and also graphically represented by fig. 7.

TABLE III.—Mean velocities of the north or south and east or west components of the wind at Bombay for each hour of the day in the months of July and August 1867 to 1870; also the mean diurnal variations for the same period.

Bombay Civil Hours	0 to 1.	1–2.	2–3.	3–4.	4–5.	5–6.	6–7.	7–8.
N. or S. component	5·67 s.	5·47 s.	5·33 s.	5·33 s.	4·85 s.	4·36 s.	4·43 s.	4·87 s.
Variation	1·02 s.	0·82 s.	0·68 s.	0·68 s.	0·20 s.	0·29 N.	0·22 N.	0·22 s.
E. or W. component	15·64 w.	16·11 w.	16·03 w.	16·07 w.	15·80 w.	15·78 w.	14·72 w.	14·90 w.
Variation	0·47 E.	0·00	0·08 E.	0·04 E.	0·31 E.	0·33 E.	1·39 E.	1·21 E.

Bombay Civil Hours	8–9.	9–10.	10–11.	11–12.	12–13.	13–14.	14–15.	15–16.
N. or S. component	4·42 s.	4·51 s.	4·97 s.	4·77 s.	4·39 s.	4·19 s.	4·41 s.	3·97 s.
Variation	0·23 N.	0·14 N.	0·32 s.	0·12 s.	0·26 N.	0·46 N.	0·24 N.	0·68 N.
E. or W. component	14·81 w.	14·98 w.	15·76 w.	16·44 w.	17·42 w.	17·39 w.	17·90 w.	17·90 w.
Variation	1·30 E.	1·13 E.	0·35 E.	0·33 w.	1·31 w.	1·28 w.	1·79 w.	1·79 w.

Bombay Civil Hours	16–17.	17–18.	18–19.	19–20.	20–21.	21–22.	22–23.	23–0.
N. or S. component	3·71 s.	3·78 s.	3·90 s.	4·29 s.	4·57 s.	4·86 s.	5·26 s.	5·29 s.
Variation	0·94 N.	0·87 N.	0·75 N.	0·36 N.	0·08 N.	0·21 s.	0·61 s.	0·64 s.
E. or W. component	17·71 w.	17·31 w.	16·41 w.	15·66 w.	16·25 w.	15·23 w.	15·33 w.	15·00 w.
Variation	1·60 w.	1·20 w.	0·30 w.	0·45 E.	0·14 w.	0·88 E.	0·78 E.	1·11 E.

The mean components for the whole period are 46·5 S. and 16·11 W.

During these two months the south-west monsoon is at its height at Bombay, and the wind is more boisterous and irregular in strength, though not in direction, than at any other part of the year; the observations are consequently insufficient to give a very regular curve, but it is sufficiently regular to justify conclusions being drawn from its

more salient features. The smoothed curve has been calculated from the original one by means of the first three terms of BESSEL'S formula. It clearly exhibits a *double* period like the north and south variation and like the barometer variation, and (remembering that no attempt has been made to eliminate the portion of the land- and sea-breeze which probably still remains) its general resemblance when inverted to the barometer-curve (fig. 2) is very remarkable. The part of this variation which contains the double period, and which will be supposed independent of the land- and sea-breeze, will hereafter be called the *longitudinal* diurnal variation of the wind, to distinguish it from the whole east and west movement given in Table I., and from the pure land- and sea-breeze.

6. If we again make the same assumption as before, regarding the nature of the land- and sea-breeze, viz. that its direction is completely represented by the line A B (fig. 1), its effect in modifying the north and south double diurnal variation of the wind may be approximately eliminated by measuring the north and south components from the line A B as the datum line, instead of from the east and west line. This has been done by means of the expression

North component of double diurnal wind variation = north component of whole wind variation as given in Table I. + $\tan 18\frac{1}{2}^\circ \times$ east component of whole wind variation as given in Table I., ... (4)

and the following variation obtained, which will hereafter be called the *meridional* diurnal variation of the wind, to distinguish it from the whole north and south movement given in Table I., and from that part of it which belongs to the land- and sea-breeze.

TABLE IV.—Meridional Diurnal Variation of the Velocity of the Wind at Bombay.

Bombay Civil Hours	0 to 1.	1–2.	2–3.	3–4.	4–5.	5–6.	6–7.	7–8.
Velocity in miles per hour	0·44 S.	0·23 S.	0·24 S.	0·09 N.	0·45 N.	0·64 N.	0·62 N.	0·47 N.
Bombay Civil Hours	8–9.	9–10.	10–11.	11–12.	12–13.	13–14.	14–15.	15–16.
Velocity in miles per hour	0·43 N.	0·03 S.	1·02 S.	1·53 S.	1·63 S.	1·70 S.	1·07 S.	0·40 S.
Bombay Civil Hours	16–17.	17–18.	18–19.	19–20.	20–21.	21–22.	22–23.	23–0.
Velocity in miles per hour	0·48 N.	0·97 N.	1·54 N.	1·61 N.	1·00 N.	0·36 N.	0·10 S.	0·37 S.

This variation is also graphically represented by fig. 8. Its value of course depends on the correctness of the assumption as to the nature of the land- and sea-breeze, which may be only approximately true, and the variation may therefore be subject to correction hereafter when the exact nature of the land- and sea-breeze becomes known.

7. It will be observed that the great distinguishing feature of the diurnal variation of the barometer, viz. the double period, is the most prominent one in the meridional

diurnal variation of the wind; and the same feature has been shown to be present in the longitudinal variation also; hence we naturally infer that the phenomena may be in some way interdependent, and are led to inquire after the nature of their relationship.

Confining our attention for the present to the meridional variation, it is difficult to conceive how any local peculiarity of geographical position could so modify the land- and sea-breeze (which we have seen follows chiefly, in its principal direction, the same law of progression as the temperature of the air) as to cause its law of progression in a north and south direction to be so widely different in character from that in the east and west direction as the variations in Table I. show it to be; and much more difficult to conceive how that modification (if it may be regarded as such) of the strictly local phenomenon which we know the land- and sea-breeze to be, should follow a law of progression similar to that of the diurnal variation of the barometer, which is perhaps the most universal and regular of all meteorological phenomena. It seems far more probable that the variation represented by fig. 8 is not a simple modification of the land- and sea-breeze by local peculiarities, but an indication of the existence of a double diurnal variation in the general movements of the atmosphere, as universal as, and moving synchronously with, the double diurnal variation of the barometer, but which has never before been noticed because of the unsuitable nature of all wind observations made before the invention of ROBINSON'S anemograph for exhibiting a variation of this kind; and it is not unreasonable to expect that similar variations will be found at other tropical stations by similarly reducing a sufficiently long series of suitable wind observations*. Now regarding that part of the diurnal variation of the wind at Bombay which is not directly attributable to the land- and sea-breeze as a universal phenomenon, perhaps its most surprising feature is that the hours about noon should occupy a position furthest removed to the *southward* of the mean direction-line A B, a feature which appears to be in direct opposition to the principles of HADLEY'S theory of the trade-winds, which is the theory that explains satisfactorily the land- and sea-breeze, and in which the wind is always supposed to blow towards the heated region, not *away from* it as shown by that feature of the variation; for, according to that theory, we should expect to find a decided tendency of the wind to blow from the north at that time in the northern hemisphere. And this feature is the more surprising when viewed side by side with the more extensive east and west movement, which is in perfect accordance with the theory.

Speaking about the sun's heating action on the atmosphere, and the effects resulting therefrom, Sir J. HERSCHEL has remarked, in his 'Meteorology,' art. 172:—"When anemometry is further perfected we may expect to trace the influence of this chain of causation into a morning and evening tendency of the wind (on a long average of observations) to draw *towards* the points of sunrise and sunset, to compensate the overflow from off the heated hemisphere which takes place aloft in a contrary direction."

* Observations of the direction of the wind are of no value for this purpose, unless combined with their corresponding observations of the velocity (not pressure) of the wind.

The expectation here expressed is certainly not realized by the diurnal wind-curve for Bombay; but it may not therefore be inferred that such a tendency does not exist, and may not eventually be traceable. The inference that may be drawn is that the same cause, working in an unexpected manner, produces other effects of an opposite nature which completely overwhelm the expected tendency, of whose existence, however, in a much smaller degree, there can be no doubt. But the principles of HADLEY'S theory fail also to explain the double reversal in the north and south direction which the wind undergoes daily; for, in accordance with them, the wind would be reversed in direction but once a day, just as in the case of the land- and sea-breeze, seeing that the temperature rises and falls but once a day. Turning to the longitudinal variation, which is approximately represented by fig. 7, the same difficulty is encountered in attempting to explain the double reversal of this curve by the same principles; and the directions of the wind indicated in the morning and afternoon hours are exactly the reverse of those expected by Sir J. HERSCHEL in the remark quoted above.

8. It seems highly improbable, then, that the meridional and longitudinal variations of the wind at Bombay are part of a system of convection-currents, such as would satisfy the requirements of HADLEY'S theory. The form of the curves seems rather to suggest the notion of a general bodily movement of the atmosphere (its lower strata as well as its upper) *outwards* in all directions from the middle of the hemisphere which is being heated *towards* the middle of that which is being cooled, succeeded by oscillatory movements consequent upon the disturbance of equilibrium thus caused. The notion of a general outflow of air (not an upper surface overflow merely) from the heated hemisphere has already been advanced by Sir JOHN HERSCHEL in his explanation of the diurnal variation of the barometer*; but he does not seem to have suspected that there would be more than one complete oscillation in the twenty-four hours, or that these movements of the air would be more marked than the convection-currents already referred to. After explaining that the heat of the sun produces on the air of one hemisphere a "considerable elevation of the lines of equal density [which when so elevated cease to be statical level lines], while the nightly chill on the other side acts in a contrary way on the opposite hemisphere," he says, "an indirect effect" on the barometer "results from the elevation of the surface of equilibrium on one side and depression below it on the other. To form some rough estimate of this effect, whose exact calculation would be difficult, we must consider that an elevation of 363 feet on one side [taking, *exempli gratiâ*, 20° Fahr. for the difference of day and night temperature] and a similar depression on the other, correspond to a slope of $3''\cdot5$ at the common boundary of the two hemispheres, down which the centre of gravity of each aërial column situate on that boundary (being unsupported laterally) tends to glide. The effect of this will be the production of *a general movement of air setting* OUTWARDS FROM *the heated hemisphere*, and which, though feeble (as its velocity would at its maximum hardly exceed a mile an hour), yet acting over the whole circumference of a great

* See HERSCHEL'S 'Meteorology,' art. 77 *a*.

circle of the globe, would transfer a sensible fraction of the whole atmosphere backwards and forwards."

Whether such a system of diurnal wind-currents as that which has been supposed, having a second complete oscillation during the night, is really a universal phenomenon, must be determined by extended observation and investigation in other localities; and whether the currents are originated and propagated in the manner that has been suggested, or whether they do not rather owe their origination in a more direct manner to the diurnal fluctuations of the temperature of the air*, it is perhaps premature to speculate; but in the mean time it appears to be worth while to compare the observations that are available, with the conclusions that may be drawn from the hypothesis of the existence of such currents, and to mark the relations that will be found to obtain between the diurnal variations of the wind and other meteorological phenomena.

9. If such a system of diurnal wind-currents really exists in nature, we should expect to find the ordinates of the two curves representing the meridional diurnal variations of the wind for the northern and southern hemispheres exactly reversed in direction, that they increase in range with the latitude in both hemispheres, and vanish at the equator. We should also expect to find that the range of the curve for each place of observation has a yearly variation corresponding to the sun's change of declination, being smallest when the sun's zenith distance is smallest and increasing as it increases, and *vice versâ*. Such a variation in range is clearly shown by the mean monthly curves for Bombay. They give the following diurnal ranges, which are the differences of the mean ordinates for $12\frac{1}{2}$ and $18\frac{1}{2}$ hours in each month, measured in the same manner as those given in Table IV.

TABLE V.—Ranges of the Meridional Diurnal Variation of the Wind and the Land- and Sea-breeze at Bombay, and the Ratios of the latter to the former.

	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
Range of meridional variation	6·1	6·1	3·6	3·2	1·7	0·8	0·2	1·6	2·3	4·5	5·9	5·2
Range of land- and sea-breeze....................	14·8	16·1	17·5	16·2	11·9	8·5	2·8	4·1	8·5	14·3	16·9	14·9
Ratios..........................	2·3	2·6	4·9	5·0	7·0	10·6	14·0	2·6	3·7	3·2	2·1	2·9

These ranges furnish another argument in favour of the meridional diurnal variation of the wind having an origin independent of that of the land- and sea-breeze; for if both were a consequence of the same local influences, they would most probably vary in such

* The fact that the curve (fig. 8) attains its maximum south position not long after noon (the time when any particular place is receiving heat most rapidly from the sun), and *before* (not after) the time of maximum temperature, which occurs about $14\frac{1}{2}$ hours, appears to point to a direct action of the heated air in expanding itself *outwards* as well as upwards; for if the south current were produced solely in the manner suggested by Sir JOHN HERSCHEL, we should expect it to attain its maximum strength *after* the time of maximum temperature, not before it. The same feature which has here been pointed out as appertaining to fig. 8 will hereafter be seen to exist in similar curves for other places (see figs. 12, 13, and 14).

a manner that the ratio of one to the other would be constant. The numbers in the third line of Table V. show the mean diurnal ranges of the land- and sea-breeze between $7\frac{1}{2}$ and $15\frac{1}{2}$ hours in each month of the year, the values for these hours having been obtained in the same manner as those given in Table II. They appear to show that the two variations are not the effects of the same persistent *local* influences.

10. Our attention has thus far been chiefly confined to that part of the diurnal variation of the wind which manifests itself in the direction of meridian lines; but the same considerations would lead us to expect an east and west diurnal variation also, of a somewhat similar character, showing that the wind blows away from, not towards, the sun, and therefore from the east during the morning hours, and from the west during the afternoon hours, and having similar oscillatory movements during the night. Reasons for believing that such a variation does really exist have been given in paragraph 5. Its times of maxima and minima will probably be about the same time at which the meridional variation is at its mean positions, and *vice versâ*; and its directions will, unlike the meridional variation, be the same at the same times at places in both hemispheres that are equidistant from the equator.

Unfortunately the observations for Bombay alone will not suffice for the exact determination of the nature of the mean longitudinal diurnal variation of the wind for the whole year, until the precise character of the land- and sea-breeze has been found by a comparison of the observations with similar ones made elsewhere; but, judging from what has preceded, we may assume as a first approximation to the truth, and for the sake of carrying the investigation a step further, that it is similar to the meridional variation, when the north components of the latter are taken to represent the west components of the former, but earlier in phase by about three hours.

Taking, then, the meridional variation as a type of the longitudinal variation, and combining the two, we have the epitrochoidal curve represented by fig. 9, which may be regarded as a typical curve representing the diurnal variation of the wind in low northern latitudes; and again combining the two after reversing the meridional variation, we get the curve represented by fig. 10, which may be regarded as a typical curve representing the diurnal variation of the wind in low southern latitudes.

The curves show a double diurnal right-handed rotation, in the same direction as the hands of a watch, for the northern hemisphere, and a double diurnal left-handed rotation, in the opposite direction to watch-hands, for the southern hemisphere.

11. In the curve (fig. 1) showing the mean diurnal variation of the wind at Bombay, the *double* diurnal rotation is converted into a single rotation by the influence of the land- and sea-breeze; but the tendency towards a double rotation is well marked, and the mean diurnal variation for the months July and August, when the effect of the land- and sea-breeze is very slight, clearly exhibits the double rotation. This variation is given in Table III., and represented graphically by fig. 11.

12. The following extracts from the discussion of the diurnal variations of meteorological phenomena for St. Helena, 1841 to 1843, by General Sir EDWARD SABINE, are almost an exact description of what would follow from the superposition of a diurnal variation like

that represented by the typical curve (fig. 10) upon the south-east trade-wind of that station, and they appear to put beyond doubt the existence of a double diurnal left-handed rotatory variation of the wind in southern low latitudes.

"From Table XLI. we learn that the wind is more easterly generally during the hours of the day than during the night, and that it is *most easterly about noon.* The direction varies little during the night, but there is a tendency to a *more southerly* direction about *daybreak*, and *just after sunset.* The force of the wind appears to have a *decided maximum* between 22^h and 23^h *, and a *minimum* about 4^h. From 5^h or 6^h to 15^h it remains nearly stationary, except that there is a tendency to a *second maximum* at 11^h shown in both years, *followed by a minimum* also of inferior character. At 13^h, at 0^h, and 16^h the pressure coincides with the mean of the twenty-four hours."

The variation in direction has also two maxima and two minima with regular progressions from one to another, and the turning-points occur at intervals of about six hours.

13. Having advanced reasons for believing that a regular diurnal variation in the movements of the atmosphere does really exist, and that it is probably universal, and having shown, to the extent to which the limited nature of the observations permit, the probable character of that variation, it may now be shown that the diurnal variation of the barometer is directly deducible from the wind variation. The best way of showing this will perhaps be to adopt the suggestions recently made by Dr. BALFOUR STEWART, and to suppose the existence of several "meteorological blockades." A figure will best illustrate what is intended (see Plate XXXIV. fig. 15).

Let W E represent the earth's equator, divided into hourly intervals, and let the horizontal lines above and below it represent parallels of north and south latitude respectively. The arrows will then indicate the directions towards which the wind is blowing at the times at which they are placed, in accordance with the typical curves fig. 9 and fig. 10. They are marked only for those times when the winds are at one or other of the four cardinal directions; but it is to be understood that there is a gradual progression from one to the other with the time, producing two right-handed rotations along the parallel of north latitude, and two opposite rotations along the parallel of south latitude; and that at the equator the wind gradually dies away to a calm, and is then succeeded by a wind in the opposite direction, which gradually increases to a maximum. Let meridian lines be drawn through those times when the meridional variation of the wind on the parallels of latitude passes through zero, which are about the times when the longitudinal variation attains its maxima east and west positions; these lines will divide the space between the parallels of latitude into four areas, *a*, *b*, *c*, and *d*, the boundaries of which may be taken to represent those of four separate blockades. An inspection of the figure will show that air is flowing out of the areas *a* and *c* in all directions, and flowing into the areas *b* and *d* from all directions. A barometer placed in the area *a* or *c* will therefore show a diminishing pressure, while one placed in the area *b* or *d* will show an increasing pressure.

* Astronomical reckoning.

Or we may suppose the figure to represent the winds of a system which revolves about the earth with the sun from east to west, and hence each place of observation between the two parallels of latitude will successively pass from west to east through the various conditions of the several areas. Take, for example, a station situated on the equator at the time 6 hours; air is then flowing towards it from all directions, and consequently at that time the barometer is rapidly rising; when the place has advanced to, say, 8 hours, air is still flowing towards it from the north and south, but with a less velocity than when it was at 6 hours; air is also flowing towards it from the east but leaving it on the west, though less rapidly, and the barometer is still rising, but less rapidly than at 6 hours; when the station has advanced to $9\frac{1}{2}$ hours air has ceased to blow towards it from the north and south, and it is importing just as much air from the east as it is exporting on the west; the barometer is now stationary and has reached a maximum. When the place arrives at 11 hours, the air has begun to flow outwards towards the north and south, and more air is leaving it on the west than is blowing towards it from the east, and in consequence the barometer has begun to fall. At about 13 hours air is leaving the place in all directions and the barometer is falling rapidly, and continues to fall until the station reaches 16 hours, when air has ceased to flow from it towards the north and south, and is leaving it on the east at the same rate at which air is being received from the west; the barometer has now reached its minimum position and is again stationary. As the station advances still further, air begins to blow towards it from the north and south, and to leave it less rapidly on the east than it receives air from the west, and the barometer begins to rise; about 19 hours, air is flowing towards the station from all directions and the barometer is rising rapidly, and it reaches a second maximum at about 22 hours, when the air has ceased to flow towards the station from the north and south and is blowing inwards on the east at the same rate at which it is blowing outwards on the west. From 22 hours to $9\frac{1}{2}$ hours the same cycle of changes as that which occurs from $9\frac{1}{2}$ hours to 22 hours is repeated, but on a less extensive scale. The same results will follow for a station situated north or south of the equator, if it be borne in mind that the north and south winds increase in strength with the distance of the place from the equator.

It will be observed that the movements of the barometer deduced from the figure are all in accordance with observation.

14. The curves fig. 9 and fig. 10 are also of some importance, as will presently appear, when viewed in connexion with the "law of gyration" propounded by Professor Dove; for they will be seen to accord with some of the results of his investigations, viz. the marked tendency of the wind to rotate in a right-handed direction in the northern hemisphere, and in the opposite direction in the southern hemisphere.

15. The whole of the wind which blows at Bombay on any particular day may be regarded as made up of three distinct parts:—1st, that due to the double diurnal variation of the wind, and which is most persistent in its character; 2nd, the land- and sea-breeze, which is also very persistent in all except the monsoon months, June, July, August, and September; and 3rd, that wind which remains after the elimination of the

double diurnal variation and the land- and sea-breeze, and which may be called the daily normal wind (this wind is the most irregular in direction and variable in velocity). The mean resultant wind for the whole year is represented by the line C F, fig. 1*. When all three winds are blowing normally there will be no rotation of the vane, but only a diurnal oscillation right and left about the daily normal wind. This is the most usual condition of the vane. The range of the oscillations will be very small if the daily normal is very strong, and will increase as the normal diminishes in strength. But whenever the daily normal wind becomes so small or varies in direction so as to lie wholly within the diurnal-variation curve, a single right-handed revolution of the vane will occur on that day, but it will not be a uniform movement all round the compass. Suppose, for instance, that the daily normal is a north wind of velocity one mile per hour; and let the thick line C D in fig. 1 represent this normal, then lines drawn from the point D to any part of the diurnal-variation curve will show the direction of the vane at the times indicated along the course of the curve and to which the lines are drawn. It will be observed that the vane will alter its direction very gradually in the afternoon hours, and rather quickly between 21 and 0 hours; that it will be almost steady at east from 6 to 9 hours, after which a very rapid movement will take place, changing its direction 180° in about three hours. Such movements of the vane are of very frequent occurrence at Bombay during most of the year, but especially during the month of October, when the daily normal wind has a smaller velocity than at any other time of the year and is very variable in direction. Professor DOVE pointed out the fact that right-handed rotations of the vane at Bombay were more numerous in October than in any other month of the year; and he suggested that the operation of local causes might account for the excess, but he left the point to the decision of the observer. The foregoing explanation of right-handed rotations of the vane throughout the year affords also an explanation of the greater number of rotations in October, and shows it to be due to the fact that the daily normal winds of that month are smaller and more variable than in any other month, and therefore lie more frequently *within* the diurnal-variation curve. A separate treatment of the daily normal winds, so as to show their variability at different times of the year, is now in progress, and it brings out the fact here mentioned very prominently. Further, whenever the land- and sea-breeze and also the daily normal are simultaneously almost entirely suspended (which, however, rarely occurs, and never except during the monsoon months), there will be a double rotation of the vane in one day, the movement round the compass approaching more and more nearly to uniformity of progression as the land- and sea-breeze and the daily normal become less and less.

It will be noticed that the daily normals which blow from different directions will all be differently modified by the superposition upon them of the diurnal variation of the wind:

* The almost exact coincidence of the direction of the resultant wind for the whole year with that of the sea-breeze is remarkable; and the fact seems to point to the same cause for the origination of one as for the other, viz. the higher temperature (on the average) of the air over the land compared with that of the air over the sea. Observations made on the eastern sea-board of India will show whether there is any truth in this conjecture.

suppose, for instance, that the daily normal is a north wind with a constant velocity throughout the day of ten miles per hour, and that a diurnal variation like that represented by fig. 1 is superimposed upon it, then at $21\frac{1}{2}$ hours and 11 hours the vane will be unaltered, but the wind will be increased in velocity at $21\frac{1}{2}$ hours, and diminished in velocity at 11 hours, whilst at $7\frac{1}{2}$ hours the vane will be deflected furthest to the right, and at $15\frac{1}{2}$ hours furthest to the left. A daily normal from the south will be oppositely affected both with regard to velocity and direction, supposing the observer to face the wind. Next, suppose that the daily normal is a wind from the west of constant velocity and of the same strength as before, then at 13 hours and 22 hours the vane will be unchanged, but the wind will have increased in velocity at the former time and diminished at the latter; whilst at $18\frac{1}{2}$ hours the vane will be deflected furthest to the right, and at $7\frac{1}{2}$ hours furthest to the left. An east normal wind will be oppositely affected both as regards direction and velocity. Similarly, for daily normals from other directions, there will be hours (different for each different normal) when the vane will be unaffected by the superposition of the diurnal variation, but when the wind will be modified in velocity, and other regularly recurring times of the day when each different normal will be deflected to its extreme right and left positions; but these times will not be the same for any two different normals. Hence arise many apparently fortuitous movements of the vane, which, however, may be reduced to order by the foregoing method of separation.

16. Having now acquired a knowledge of the nature of the diurnal variation of the wind at Bombay, and the influence which it exerts on the movements of the vane, it is evident from an examination of the anemograms that by far the greater part of the right-handed rotation of the vane at Bombay is due to the *diurnal variation* of the wind rather than to a veering round of the daily normal wind; and it will be needful to make a special investigation of the wind records at Bombay, eliminating the effects of the diurnal variation, before it can be said that they show an excess of "direct" over "retrograde" rotation due to the cause assigned by Professor DOVE in his 'Law of Storms.'

17. The anemograms of the seven British observatories, published in the 'Quarterly Weather Reports of the Meteorological Office,' show numerous instances in the summer months of *diurnal* right-handed rotations of the vane similar to those which occur at Bombay, and very many cases of like diurnal modifications of a daily normal from the same direction. As instances of the former kind, may be mentioned the anemograms for Falmouth for the 30th June, 1st and 2nd July, 1869; and of the latter kind those for Stonyhurst for the 30th June and 1st July, 1869. Such instances appear to show that a systematic *diurnal* variation of the wind obtained in the British Isles; and for the sake of testing this point, an experimental reduction of fifty of the Falmouth anemograms for days between the 1st April and 2nd September, 1869, has been made. Those days on which the velocity exceeded 15 miles per hour for the whole day, or a large portion of it, were rejected as disturbed days. The tabulations and reductions were made exactly in the same manner as the Bombay observations are tabulated and reduced, so that the results are strictly comparable with those for Bombay. The results are contained in the following Table, and also graphically represented by fig. 12.

TABLE VI.—Mean North or South and East or West components of the Wind at Falmouth for fifty days between the 1st April and 2nd September, 1869, for each hour of the day, also their mean diurnal variations for the same period.

Falmouth Civil Hours......	0 to 1.	1–2.	2–3.	3–4.	4–5.	5–6.	6–7.	7–8.
N. or S. component	2·9 N.	3·5 N.	3·8 N.	3·5 N.	4·1 N.	3·5 N.	3·1 N.	5·8 N.
Variation	2·6 N.	3·2 N.	3·5 N.	3·2 N.	3·8 N.	3·2 N.	2·8 N.	2·5 N.
E. or W. component	2·0 W.	1·9 W.	1·7 W.	1·3 W.	1·4 W.	0·5 W.	0·8 W.	1·2 E.
Variation	1·8 W.	1·7 W.	1·5 W.	1·1 W.	1·2 W.	0·3 W.	0·6 W.	1·4 E.

Falmouth Civil Hours......	8–9.	9–10.	10–11.	11–12.	12–13.	13–14.	14–15.	15–16.
N. or S. component	1·8 N.	0·2 S.	2·1 S.	3·3 S.	4·4 S.	4·4 S.	3·9 S.	2·8 S.
Variation	1·5 N.	0·5 S.	2·4 S.	3·6 S.	4·7 S.	4·7 S.	4·2 S.	3·1 S.
E. or W. component	2·2 E.	3·1 E.	4·0 E.	2·8 E.	1·6 E.	1·2 E.	0·2 W.	0·0
Variation	2·4 E.	3·3 E.	4·2 E.	3·0 E.	1·8 E.	1·4 E.	0·0	0·2 E.

Falmouth Civil Hours......	16–17.	17–18.	18–19.	19–20.	20–21.	1–22.	22–23.	23–0.
N. or S. component	2·2 S.	0·8 S.	0·3 N.	1·9 N.	2·2 N.	1·7 N.	2·2 N.	2·5 N.
Variation	2·5 S.	1·1 S.	0·0	1·6 N.	1·9 N.	1·4 N.	1·9 N.	2·2 N.
E. or W. component	1·2 W.	2·0 W.	1·8 W.	2·0 W.	1·6 W.	2·2 W.	2·1 W.	2·0 W.
Variation	1·0 W.	1·8 W.	1·6 W.	1·8 W.	1·4 W.	2·0 W.	1·9 W.	1·8 W.

The mean components for the whole period are 0·3 N. and 0·2 W.

Considering the small number of observations from which it is deduced, the curve is a remarkably regular one, and accords in many respects with the typical curve, fig. 9. The rotation is right-handed; the morning hours occupy the east side of the curve, the hours about midday are to the south, and the afternoon hours to the west, while the midnight hours are crowded together towards the north-west, but there are no definite indications of a double diurnal rotation. This figure will probably interest many magneticians; for when it is turned in a right-handed direction through an angle of *about* 90° in the plane of the paper, it bears a very striking resemblance to a curve which represents the mean diurnal variation of the earth's magnetic force in a horizontal plane at Greenwich; and which is published in the Greenwich Observations for 1867.

18. The Toronto observations of the wind also show a diurnal variation which rotates in a right-handed direction. The following results (see Table VII., p. 16) are deduced from the "Meteorological Abstracts, Toronto 1854–1859," Tables LII. and LIII.

Fig. 13 is a graphic representation of this variation, from which it will be seen that the diurnal variation of the wind at Toronto has similar features to those of the Falmouth curve, and that it resembles the typical curve (fig. 9) in the same particulars. There is an absence of any distinct indication of a *double* diurnal rotation in this case also.

TABLE VII.—Mean North or South and East or West components of the Wind at Toronto for each hour of the day, during the years 1854 to 1859 inclusive, also their mean diurnal variations for the same period.

Toronto Civil Hours	0 to 1.	1–2.	2–3.	3–4.	4–5.	5–6.	6–7.	7–8.
N. or S. component	1·65 N.	1·78 N.	1·78 N.	1·75 N.	1·67 N.	1·66 N.	1·71 N.	1·65 N.
Variation	0·64 N.	0·77 N.	0·77 N.	0·74 N.	0·66 N.	0·65 N.	0·70 N.	0·64 N.
E. or W. component	1·53 W.	1·49 W.	1·50 W.	1·42 W.	1·35 W.	1·30 W.	1·43 W.	1·49 W.
Variation	0·40 E.	0·44 E.	0·43 E.	0·51 E.	0·58 E.	0·63 E.	0·50 E.	0·44 E.
Toronto Civil Hours	**8–9.**	**9–10.**	**10–11.**	**11–12.**	**12–13.**	**13–14.**	**14–15.**	**15–16.**
N. or S. component	1·49 N.	1·02 N.	0·38 N.	0·25 S.	0·59 S.	0·61 S.	0·52 S.	0·00
Variation	0·48 N.	0·01 N.	0·63 S.	1·26 S.	1·60 S.	1·62 S.	1·53 S.	1·07 S.
E. or W. component	1·65 W.	2·00 W.	2·15 W.	2·36 W.	2·54 W.	2·64 W.	2·65 W.	2·56 W.
Variation	0·28 E.	0·07 W.	0·22 W.	0·43 W.	0·61 W.	0·71 W.	0·72 W.	0·63 W.
Toronto Civil Hours	**16–17.**	**17–18.**	**18–19.**	**19–20.**	**20–21.**	**21–22.**	**22–23.**	**23–0.**
N. or S. component	0·58 N.	0·85 N.	1·07 N.	1·23 N.	1·31 N.	1·50 N.	1·58 N.	1·58 N.
Variation	0·43 S.	0·16 S.	0·06 N.	0·22 N.	0·30 N.	0·49 N.	0·57 N.	0·57 N.
E. or W. component	2·53 W.	2·33 W.	2·17 W.	2·04 W.	1·95 W.	1·85 W.	1·75 W.	1·64 W.
Variation	0·60 W.	0·40 W.	0·24 W.	0·11 W.	0·02 W.	0·08 E.	0·18 E.	0·29 E.

The mean components for the whole period are 1·01 N. and 1·93 W.

19. Now, confining our attention to the northern hemisphere, and supposing the sun to have no declination, a little consideration will show that a *double* diurnal variation of the wind like that represented by fig. 9 cannot subsist in all latitudes, for such a supposition would lead to a contradiction when the pole was reached; for it would require that winds should be found there blowing in opposite directions at the same time, which is of course absurd. The two influences, however, which produce the two north and south oscillations in low latitudes may be supposed to exist at the same time even at the pole, tending to produce motion in opposite directions: the movement produced will therefore be due to the difference of these influences; and as the greater influence is that which produces the larger oscillation in low latitudes, the result will be a transference of air across the pole from the hot to the cold hemisphere, or, which is the same thing, a motion of the air *from the sun.* It follows that the diurnal variation at the pole will consist of a single rotation, the diurnal-variation curve being a circle—or, in other words, a vane placed there and influenced only by this variation will "veer" round at the uniform rate of 15° per hour. If we suppose such a variation to exist at the pole, then in middle latitudes we should expect to find the diurnal variation of the wind partaking of the characteristics both of the variation at the pole and that in low latitudes; and such

appears to be the case with the variations given for Toronto and Falmouth: the double rotation is converted into a single one in both instances; but the rate of rotation is decidedly *not uniform*, being much slower during the night than during the day, although the rate during the day is much slower than in low latitudes. Referring to the typical curve fig. 9, we see that during the day it rotates through 180° in a little over 6 hours; and from the remarks for St. Helena, it may be inferred that there the diurnal wind-curve rotates through the same distance in about the same time, whilst at Falmouth and Toronto the curve rotates during the daytime through 180° in about 9 hours. At the pole, the curve, as we have supposed it, rotates through 180° in 12 hours.

20. The results deduced from the curves that have been discussed afford a possible, if not a probable, explanation of the observed excess of "direct" rotation of the wind-vane over "retrograde" rotation in the northern hemisphere, and of the opposite excess in the southern hemisphere; and it is one that follows directly from the observed movements of the wind. They have therefore some relevance in the discussion of storms; for it should be shown that there still remains an excess of direct over retrograde rotation, after eliminating the effects of the diurnal variation of the wind, before any allowances are made for "veering" of the wind in deducing probabilities of the weather from observations made at the *same hours* of successive days; whilst they show the small magnitude of allowances that should be made for "*veering*" or "*backing*," as the case may be, in connecting observations that are made at *different hours* of the day; and by reducing the number of the movements of the vane for which reasons have still to be sought, and which would otherwise be misleading, they will increase to some extent the value of weather probabilities. Some of the foregoing remarks have been made because the writer has observed that, in an "inquiry into the connexion between strong winds and barometric differences" by the Director of the London Meteorological Office, an allowance of 45° per day has been made for the "veering" of a *strong* wind, in deducing the probable wind that would follow a certain barometric difference between two stations, in accordance with Buys Ballot's law. The subject appears to be worthy of further elucidation, prior to the adoption of daily allowances for "*veering*" in future tentative investigations of a similar nature.

21. In conclusion the writer would say that he makes no pretensions to having framed a *complete* explanation of the diurnal variations of the barometer. In their present stage, he regards the notions he has advanced more as providing a working hypothesis than as a final solution of the long-vexed question of the barometric tides. As a suggestion, it supplies in some measure a want that has long been felt, in that it points out a definite line of inquiry which cannot fail, if followed, to be productive of most valuable results. The fact that the hypothesis undesignedly forms a connexion between two meteorological phenomena (viz. the diurnal variation of the barometer and that movement of the air which Dove has called the "Law of Gyration") which have hitherto been regarded as perfectly independent of each other, and that it simultaneously explains both, appears to be in its favour; and it may be that it contains a germ of truth which, when fully developed, will form no small addition to the foundations of meteorological science.

Postscript.

Since the completion of the above discussion, the Quarterly Weather Report of the Meteorological Office for the first quarter of 1871, containing the Anemometrical Results for Sandwick Manse, Orkney, 1863–68, has been received at Bombay. From Table II. page [36] the mean north and east components for each hour of the day in the whole period have been extracted. They are as follows:—

Mean North and East components of the Wind at Sandwick Manse, Orkney, for each hour of the day from 1863 to 1868, also their mean diurnal variations for the same period.

Sandwick Manse Civil Hours	0.	1.	2.	3.	4.	5.	6.	7.
N. component	−2·65	−2·67	−2·55	−2·49	−2·34	−2·28	−2·20	−2·29
Variation	−0·27	−0·29	−0·17	−0·11	+0·04	+0·10	+0·18	+0·09
E. component	−2·90	−2·85	−3·13	−3·04	−2·99	−3·14	−3·09	−3·18
Variation	+0·27	+0·32	+0·04	+0·13	+0·18	+0·03	+0·08	−0·01

Sandwick Manse Civil Hours	8.	9.	10.	11.	12.	13.	14.	15.
N. component	−2·39	−2·50	−2·65	−2·74	−2·73	−2·58	−2·33	−2·30
Variation	−0·01	−0·12	−0·27	−0·36	−0·35	−0·20	+0·05	+0·08
E. component	−2·98	−2·98	−3·10	−3·49	−3·70	−3·69	−3·92	−3·68
Variation	+0·19	+0·19	+0·07	−0·32	−0·53	−0·52	−0·75	−0·51

Sandwick Manse Civil Hours	16.	17.	18.	19.	20.	21.	22.	23.
N. component	−2·11	−1·90	−1·86	−1·97	−2·19	−2·40	−2·45	−2·62
Variation	+0·27	+0·48	+0·52	+0·41	+0·19	−0·02	−0·07	−0·24
E. component	−3·51	−3·34	−3·11	−3·00	−2·84	−2·82	−2·84	−2·84
Variation	−0·34	−0·17	+0·06	+0·17	+0·33	+0·35	+0·33	+0·33

The mean components for the whole period are N. −2·38 and E. −3·17.

The variation of the north components shows a decided *double* period having maxima about 6 and 18 hours and minima about 0 and 12 hours, like the meridional variation of the wind at Bombay. The variation of the east components is less regular, but the double period, though not strongly marked, is nevertheless unmistakable in this variation also. It has a minimum about 14 hours and a maximum about 21 hours, a second minimum during the early morning hours and a second maximum between 8 and 9 hours, showing it to be of like character to the longitudinal variation of the wind at Bombay. The combination of these two variations produces a curve (fig. 14) which possesses the same general features as the typical curve fig. 9.

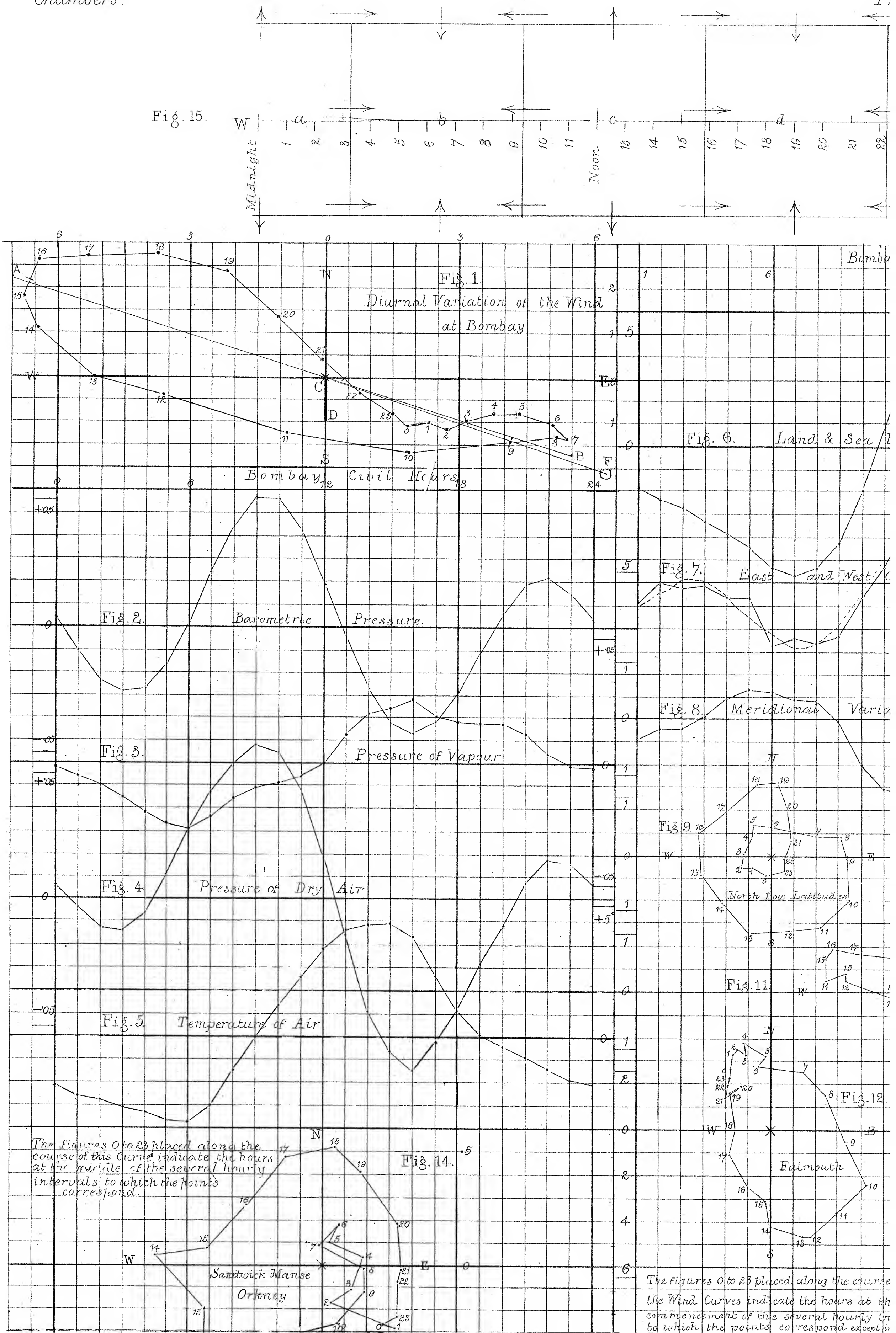
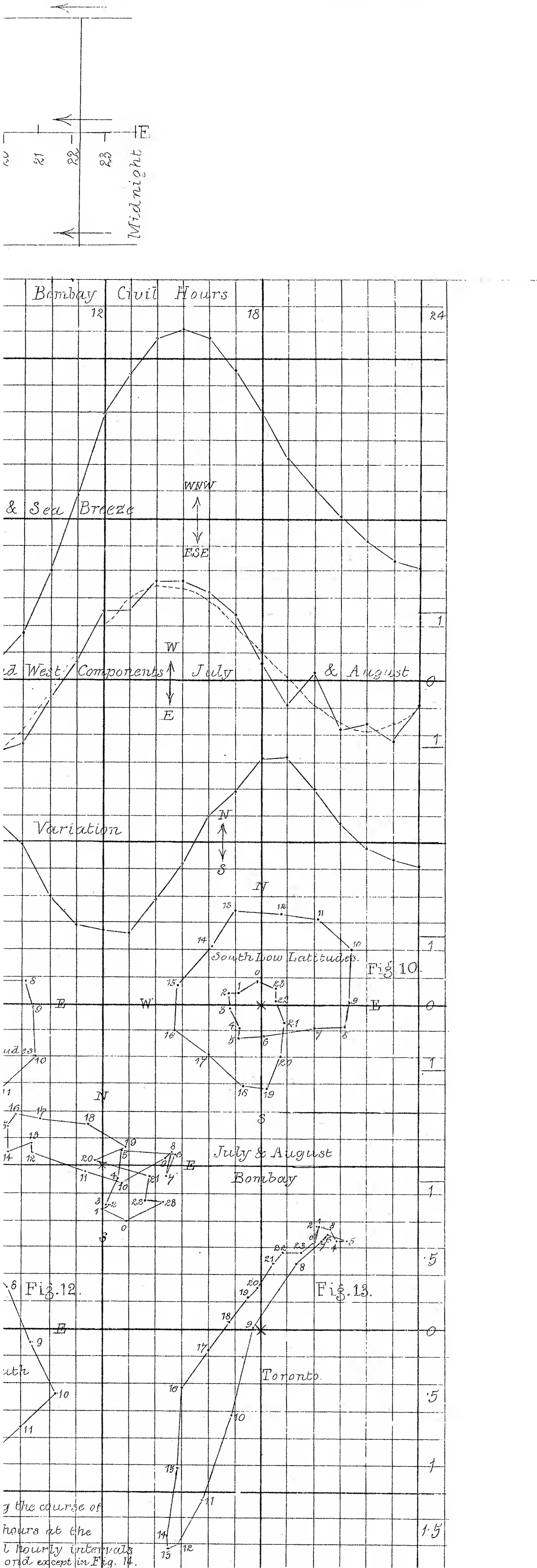


Fig. 15.
Midnight
Noon
Fig. 1.
Diurnal Variation of the Wind at Bombay
Bombay Civil Hours
Fig. 2.
Barometric Pressure.
Fig. 3.
Pressure of Vapour
Fig. 4.
Pressure of Dry Air
Fig. 5.
Temperature of Air
Fig. 14.
The figures 0 to 23 placed along the course of this Curve indicate the hours at the middle of the several hourly intervals to which the points correspond.
Sandwick Manse Orkney
Fig. 6.
Land & Sea
Fig. 7.
East and West
Fig. 8.
Meridional Varia
Fig. 9.
North Low Latitudes
Fig. 11.
Fig. 12.
Falmouth
The figures 0 to 23 placed along the course the Wind Curves indicate the hours at th commencement of the several hourly in to which the points correspond except i


E
21
22
23
Midnight
Bombay Civil Hours
12
18
24
& Sea Breeze
WNW
ESE
W
E
West Components July & August
Variation
N
S
South Low Latitudes.
Fig. 10.
July & August
Bombay
Fig. 12.
Fig. 13.
Toronto.
g the course of
hours at the
l hourly intervals
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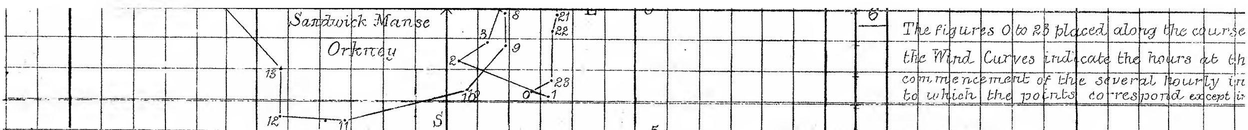
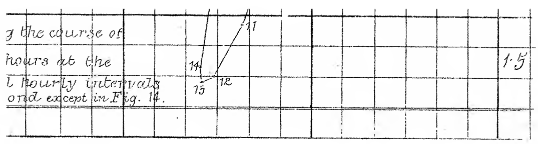


W.H.Wesley lith.



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l hourly intervals
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11
14
13
12
1·5